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Nijkamp, P.; van Oirschot, G.; Oosterman, A.

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P. Nijkamp
G. van Oirschot
A. Oosterman

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REGIONAL DEVELOPMENT AND ENGINEERING CREATIVITY: AN INTERNATIONAL COMPARISON OF SCIENCE PARKS IN A KNOWLEDGE SOCIETY

Peter Nijkamp Gudrun van Oirschot André Oosterman

Dept of Economics
Free University
Amsterdam

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Abstract

This paper finds its origin in the emerging knowledge and information society accompanying the structural economic and technological changes in our era. Based on the recognition of the critical importance of engineering creativity for regional competitiveness, the role of knowledge and information in regional development is explored. Next, the potential offered by knowledge and information centres in regional and urban growth processes is emphasized, with a particular view on the role played by the modern concept of science parks. The paper then identifies the critical success factors of science parks as an instrument of regional policy by investigating the bottlenecks in each development stage of the life cycle of a science park, based on a broad inquiry among various science parks all over the world.

1. The Changing Scene of Regional Development

In the past decade the scope and substance of regional development have drastically changed. The traditional viewpoints and policy strategies on problem regions - characterized by high unemployment, low income and low productivity, poor accessibility and insufficient level of public services - have shifted from passive support measures to active self-reliance strategies. The awareness has grown that regions are no islands in a calm sea, but part of a spatial economic network dominated by competitive forces (Nijkamp 1993). Regions which - through their competitive advantage - are able to attract a considerable share of the potential regional, national and international market will become the winners in this game (cf. Biehl 1986; Porter 1991). Thus regions may in principle be regarded as islands of innovation and entrepreneurial spirit.

This regional focus has often been advocated from the viewpoint of locational efficiency induced by both a reduction in transaction costs as a result of geographical proximity and the presence of external economies stimulating an industrial atmosphere and incubation climate. But it is increasingly recognized (see Camagni 1991) that the regional scene is extremely dynamic, which offers two more potential benefits for innovative regions:

- a collective learning process that stimulates local creativity and technogenesis through local synergies (see also Kamann and Nijkamp 1990).
- a decline in dynamic uncertainty intrinsic in technological developments and innovative processes.

Clearly, emphasis on dynamic development processes in a competitive and innovative setting leads directly into an evolutionary approach to spatial dynamics.

An important element of recent theory building in the field of regional dynamics is based on network concepts, not only in terms of material infrastructure and communication networks favouring the competitive advantages of regions, but also in terms of new network configurations of firms and services institutions aiming at achieving dynamic excellence. Networks provide proper channels for efficient logistics, marketing and sales policies, as well as for information gathering and processing.

The relevance of network views on spatial competition has also been demonstrated by the subdivision of regions into promising regions, called 3C+ regions (regions characterized by connectivity, creativity, and competence), and lagging regions, called 3C- regions (regions characterized by congestion, claustrofobia and criminality) (see also Andersson 1985, and Nijkamp 1993). Thus networks are able to offer an incubation function for new entrepreneurial strategies through an efficient interchange of knowledge and/or information, goods and people. In conclusion, access to a high quality knowledge, information, telecommunication and infrastructure network offers many possibilities for creative and new decisions and strategies of firms. This observation is once more important, as the increasing share of the service sector and the knowledge component in industrial products suggests that learning principles (learning-by-examining, learning-by-doing and learning-by-using) become a critical competitive tool: reduction of uncertainty is most probably the highest benefit in an information societity.

Traditionally, firms are supposed to face five types of uncertainty (Camagni 1991):

- information gaps caused by real world complexities
- assessment gaps caused by lack of ex ante qualitative information
- competence gaps caused by insufficient information processing abilities of decision makers
- competence-decision gaps caused by imperfect foresight into future strategic possibilities
- control gaps caused by lack of control or power on new actions.

In coping with such a wide range of static and dynamic uncertainties firms are trying to minimize risk and wrong decisions through various strategies:

- search functions
- screening functions
- transcoding functions
- selection functions
- control functions.

In doing so, firms are intrinsically dependent on their local environment, which may provide the following support mechanisms for these five functions, respectively:

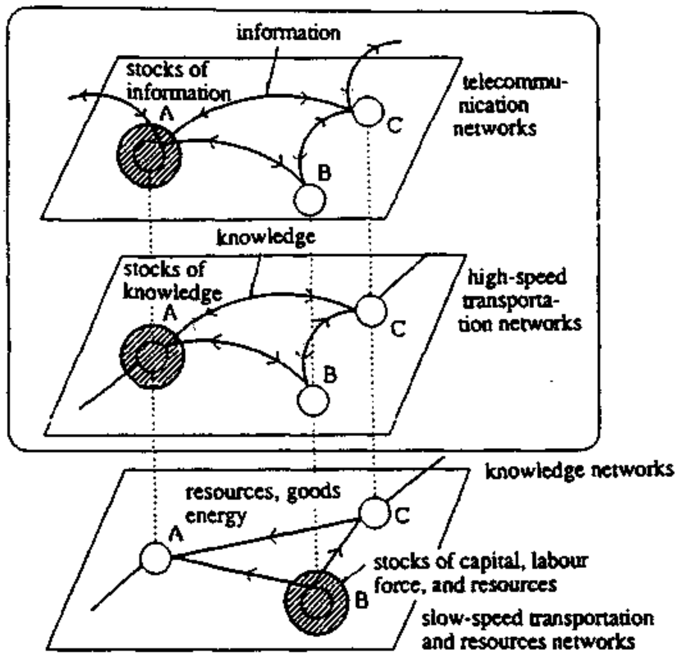
- collective information - gathering and screening functions
- signalling functions
- collective learning processes
- collective processes of developing managerial styles and decision routines
- informal decision coordination functions.

In conclusion, information and knowledge are becoming one of the most critical success factors in regional development policies. This issue will be further discussed in the next section.

2. Knowledge Infrastructure and Regional Development

The increasing knowledge and information intensity of modern production has provoked an increasing orientation of regional policy towards the creation of R&D centres, research laboratories, science parks, universities, transfer centres and related institutes for higher education (see Andersson et al. 1989). The regional economic interest in such knowledge-intensive institutes was not so much determined by the related expenditure patterns of the (relatively high income) employees of such institutes, but rather by the push effects of knowledge intensive areas. Silicon Valley, the Research Triangle, Route 128 in Boston, Tsukuba, Sophia Antipolis, and the Cambridge Science Park are well known examples of successful initiatives (cf. Hall and Markusen 1985, Rogers and Larsen 1984). Consequently, the concept of a knowledge network has increasingly come to the fore as an instrument in a regional development strategy (see also Batten et al. 1989). Such knowledge networks generate, collect and transfer scientific information via a multitude of channels and hence generate an information-rich incubator function for knowledge-based activities in both the private and the public sector. Especially the above mentioned 3C+ regions offer the necessary favourable conditions for competitive advantage. As shown by Batten et al. (1989) such regions are nodes in both material and non-material networks (see Figure 1).

Figure 1. Knowledge and information in a networked society



Source: Batten et al. (1989)

The assessment of the socio-economic impacts of knowledge centres is not an easy task (see Charles and Howells 1992; Trow and Nybom 1991), because information is scarce, many spill-overs to other areas do exist and the real effects have a long lead time. A very interesting example of university impact analysis in the Netherlands using sophisticated regional economic models can be found in Florax (1992). Even though the direct regional economic benefits are not always impressive, the generative effects of knowledge centres - in terms of attracting high tech activities - are in general regarded as the most important cornerstones of regional R&D strategies.

It is indeed noteworthy that from the viewpoint of business life, the presence of a knowledge network is increasingly regarded as a primary locational factor (see Aydalot 1984, Malecki 1984, Nijkamp 1986, Oakey et al. 1987 and Premus 1982), as it allows entrepreneurs to benefit from the presence of new information availability, while at the same time a linkage to a knowldege and information node provides access to broader national and international networks.

It is therefore no surprise that many regions in the industrialized world are increasingly reaping the fruits of a network economy in which regions, and in particular metropolitan areas, play a central role in an international competitive system. It is evident that a prerequisite for becoming 'winner' in this competitive game is to build up a flexible and innovative high-technology and high-knowledge economy. Recent experiences show that there are various alternative development options in policies regarding knowledge creation, technological restructuring and innovation. They range from large-scale top down driven initiatives (e.g., the Airbus consortium in Europe) to small-scale local initiatives (e.g., regional information systems for local retailers).

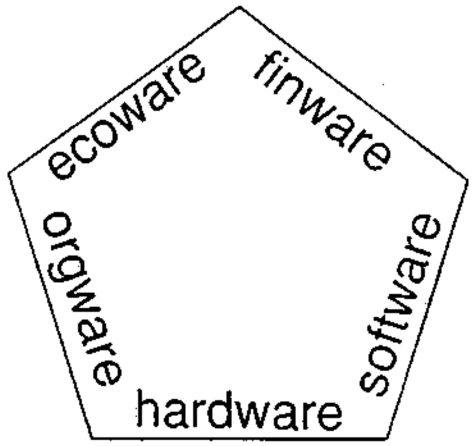
Despite the diversity in these initiatives, there is one lesson which has become a common belief among both private and public decision-makers: technological innovation (and knowledge) is not 'manna from heaven', but can be stimulated and induced by well focussed initiatives. The provision of incentives and the creation of favourable incubation conditions can generate creative and innovative behaviour of entrepreneurs. One of such stimuli is offered by the *science park* concept which is the focal point of the present paper. This concept is based on a synergetic view on scientific research and technological progress: innovations can be stimulated by locating new entrepreneurial activities in 3C+ regions (see Section 1). Such regions are a typical product of a competitive network economy. The success of a 3C+ region depends in particular on:

1) the availability of technological *hardware*, such as the existence of a good transport and communications system and the availability of land;
2) the existence and use of advanced *software*, such as the availability of a skilled and dedicated labour force, a population that is receptive to technical progress, and access to research institutes, end users and supply markets;
3) the implementation of appropriate *orgware*, e.g. the presence of supporting services and government policies favouring entrepreneurship;
4) the presence of a favourable *ecoware*, e.g., in terms of residential and cultural amenities;

5) the availability of *finware*, such as the availability of seed capital and venture capital.

The previous elements can be incorporated in a so-called *pentagon* model representing the decisive factors for successful 3C+ regions (see Figure 2).

Figure 2. The pentagon model



It is interesting to observe that the long history of Europe clearly demonstrates that the rise and fall of 3C+ regions depend to a large extent on the factors mentioned in Figure 2. The places favoured in the Hanseatic period, the Industrial Revolution, and the current Information Age were able to generate new activities as a result of favourable incubator conditions embedded in the above five pentagon factors.

Seen from the above angles, it is evident that knowledge and information nodes, which are often located in accessible industrial and commercial centres with a diverse labour market and a creative climate, are to be regarded as obvious candidates for membership of the 3C+ regions family. In this context, the phenomenon of a science park has to be understood which has become a popular policy tool in many countries. In addition to exploiting the strong features of 3C+ regions via science park initiatives, in many countries science parks have also become a part of regional policy regarding 3C- regions. This difference will undoubtedly have implications for the success and performance of science parks, as will be shown in subsequent sections.

3. Pathways to Science Parks

Technological development and economic growth are becoming increasingly intertwined phenomena. Technologically advanced products determine to a large extent the country's international competitiveness and therefore its welfare. In addition, it is also recognized that our world is at the brink of a technological revolution based on a high knowledge intensity. The impact of information technology on other sectors of the economy is expected to lead to an upswing in economic activity, and ultimately to a so called 'information society' or 'network society'.

Public decision makers and economists have become aware of this important relationship and feel that technological development ought to be stimulated. Many (especially regional) governments have therefore extended the visible hand of the state by assisting "high tech" industries and individual companies by means of new policy instruments. Many of these instruments are aimed at the formation and growth of small new technology based firms, which are considered as seedcorn of the technological revolution.

This rising interest in technology policy has been accompanied by a general belief that universities and other research institutes represent a resource, in terms of knowledge and research, that can be tapped in order to promote high technology-based growth. Some authors have even compared the role of the research institute in an information society with that of a factory in an industrial society. The increased attention for technological development and the role of research institutes in this process has led to the rise of a new concept, viz. the science park.

Science parks are property developments alongside a knowledge or research institute. Their aim is to encourage the growth and formation of both new technology based firms and research institutes or knowledge centres. To accomplish this aim a science park facilitates the transfer of knowledge between research and business life; their function is that of *engineering creativity*.

Although a large number of science parks have been set up by various government agencies - often for reasons of regional technology development -, they are by no means the only founders. Universities have been among the first park founders and in the 1980s private companies have become actively involved in science park development.

A government agency, a research institute or a private firm participates in a science park for the simple reason that it expects to benefit from its involvement (cf. Currie 1985, Dunford 1992, van Geenhuizen 1986, Gibb 1985, Klurfain-Spyridakis 1992, and Lacave 1992). To mention a few examples: a university may become more involved in industrial problems and practice, a small high-tech firm can use a university's computing facilities, and a city council may effectively promote technological development. A very interesting question then is: under what circumstances can the benefits of a science park be maximized. In other words, the central issue of this paper is: *what are the critical success factors of a science park?*

Many regional government agencies aim to build up a flexible and innovative high-technology economy by means of various customized incentives for the region at hand. The science park concept is one such incentive. It should be noted however, that nowadays various terms, such as science park, business park or incubator are being used to describe broadly the same phenomenon. We will start with some definitional and terminological remarks (see Nijkamp et al. 1992).

According to the widely used definition of the United Kingdom Science Park Association (UKSPA), a science park is:

A property based initiative which:

- has formal operational links with a university, other higher educational institutions, or a *major centre of research* (hereafter HEIs);
- is designed to encourage the formation and growth of *knowledge-based businesses* and other organizations normally resident on site;
- has a *management function* which is actively engaged in the transfer of technology and business skills to the organizations on site.

We use the term 'science park' for every such property based initiative, but it can be useful to differentiate between four different types of science and creativity based policy initiatives.

(1) *Incubators* are 'breeding grounds' for young scientists who want to commercialize their own research. An incubator centre is small, provides financial, managerial and technical assistance to the new entrepreneurs and is usually created by an HEI.

(2) *Science parks* are set up to promote the cooperation between HEIs and innovative enterprises. In order to improve the chances of a fruitful cross-fertilization of the ideas of entrepreneurs and scientists, most science parks are set up in the neighbourhood of HEIs. Although a science park often has an incubator on its site, its efforts are aimed at attracting existing enterprises.

(3) A *technopolis* encompasses the concept of a science park. Apart from promoting the commercialization of science, it tries to create a general 'receptiveness' to a society based on technology. A true technopolis has a scientific, an economic as well as a social dimension. At this moment, the only cities that qualify as a technopolis are Tsukuba in Japan and Sophia Antipolis in France. All other configurations are of a much smaller scale.

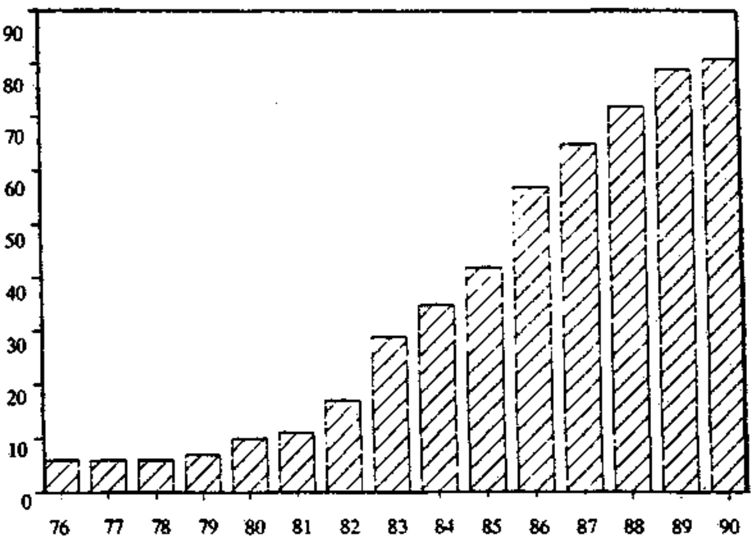
(4) A *business park* tries to promote the establishment of knowledge-based firms, but has no formal operational links with HEIs. It is therefore by definition not a science park. Foreign experience show that science parks of this type have a much higher failure rate than incubators and 'real' science parks.

The first science parks emerged in the United States during the 1950s. Europe followed in the 1970s, but science parks only started to grow rapidly in the past decade. Nowadays we find science parks - with different sizes and different degrees of specialization - in many countries: France, Great Britain, Germany, the United States, Canada, Sweden, Japan and The Netherlands.

eighties. Member states of the European Community, impressed by the success of the parks in the United States, started to create their own Silicon Valleys. Empirical evidence from the United States of substantial high technology growth in the vicinity of certain research institutes had made European politicians, facing serious economic problems and high unemployment rates in the traditional industrial areas, enthusiastic about the potential offered by science parks.

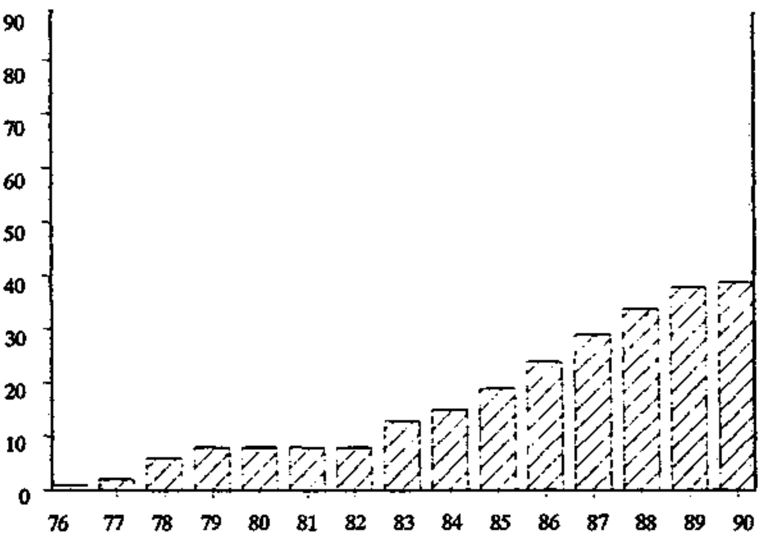
While in Europe policy makers often focused on job creation, the Japanese government announced a project aimed at economic restructuring. This so-called Technopolis project was implemented to restructure the national economy from a traditional industrial manufacturing to knowledge intensive, high value-added production (cf. Stöhr and Ponighous 1992). The number of science parks in Japan (technopoles included) jumped from zero in 1980 to one hundred and three in 1990 (see Masuda 1990). In the United States, science parks boomed as well. Although they were originally a university initiative, state and local governments as well as real estate developers joined the science park carousel. Figures 3 and 4 show the rise of science parks in the United States and the European Community, respectively (time series are not available for Japan).

Figure 3. Cumulative science park development in the United States



It was estimated by van Oirschot and Oosterman (1992) that direct employment offered by science parks is nowadays about 150,000 in the United States, 50,000 in the European Community and 25,000 in Japan. Since reliable and comprehensive data about science parks are hard to find, these estimates are rather crude. Although science parks have been growing very fast in recent years, their impact on economic development should not be overestimated. They represent only a small fraction of jobs in the high-technology sectors and a negligible percentage of total employment in the major industrial countries.

Figure 4. Cumulative science park development in the European Community



In spite of very different historical backgrounds, and of different social and economic conditions, it seems that three basic causes have led to the rapid growth of science parks in most industrialized countries: (a) a growing impact of technological development on economic growth, (b) the growing belief that universities and knowledge centres are underutilized sources of technological innovation, and (c) a change in regional policies (i.e., more bottom-up initiatives).

Furthermore, in the 1980s universities and public research institutes in almost all industrial countries faced drastic budget cuts. It was felt that science parks could grow into an additional source of income for these institutions: a direct source, through the sale or lease of land, as well as an indirect source, because an improved image would allow a university to compete better for research funds and for bright students. In a number of countries, such as the United States and the United Kingdom, universities possessed land which they were only allowed to use for academic purposes. A side-effect of these budget cuts was an increased work-pressure on academics accompanied by an increased income differential between the private and public sector, which in turn would increase their willingness to become engaged in the commercialization of scientific research.

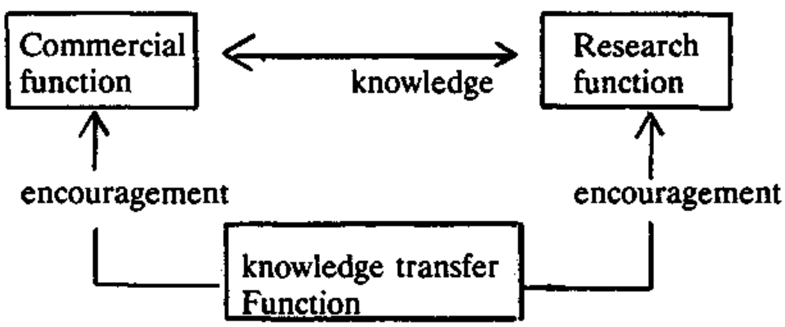
In addition, universities and private companies show an increasing social responsibility. They are more and more inclined to pursue goals which are outside their original fields of interest, viz. education/research and profit, respectively. In some instances, the motivation of a founder to set up a science park is even to contribute to the local community.

There is an increasing 'receptivity' of society towards technology, as well as an increasing awareness of the paramount impact of technological development on economic welfare. This eases the path for governments, universities and private sector parties to promote science parks.

In many regions all over the world, policy makers appear to have turned to the upgrading of *indigenous* regional resources, which may trigger new - often knowledge-based - activities (cf. Davelaar 1991, Rothwell and Zegveld 1985, MITI 1990). The motives for indigenous development can be summarized as follows: (a) local firms are more firmly committed to local interests than branch plants; (b) new technology based firms, especially small ones, contribute considerably more than proportionally to the net growth of new jobs (see Birch 1976); (c) new technology based firms are expected to offer higher salaries and higher quality jobs than relocated branch plants; (d) new technology based firms are considered to be 'footloose' (in contrast to the industries associated with the fourth Kondratieff wave, they need not be located near sources of raw materials, energy, water, etc), and (e) in providing employment stability in under-industrialized regions, small local firms are superior to manufacturing divisions or branches of large firms.

Government agencies in most industrialized countries have thus turned to the promotion of new and small high technology firms and the attraction of high technology investment as the new means of promoting regional development. In some of these countries, science parks have become an instrument of regional development. The majority of parks in Great Britain (see Henneberry 1984) and Japan (see Tatsuno 1986), for instance, has been created to relieve regional imbalances. In all cases, science parks appear to serve simultaneously a research function, a commercial function and a knowledge transfer function (see also Figure 5).

Figure 5. The science park concept



4. The Operation of Science Parks

The stages from planning a science park to its implementation as a sustainable success story of engineering creativity are manifold and long lasting. Here we will report on findings from a recent postal survey questionnaire among several science parks all over the world (see Van Oirschot and Oosterman 1992), with a special view on the following factors of decisive importance:

- strategic planning
- organization
- financing
- design and architecture
- management, and
- external environment

All these factors will succinctly be dealt with.

4.1 Strategic planning

The strategic planning process which forms the first necessary step for a start-up phase of a science park is represented in Table 1.

Table 1. The strategic planning process of a science park

PHASE	ACTIVITY	PERIOD
Goal setting	Definition of product	Before construction
Strategy formulation	Identification of product and market	
Strategy implementation	Organization	
	Financing	
	Park design	During construction
	(Operational) Management	After construction

Given the multiplicity of actors involved, due attention has to be given to potential conflicts between objectives of various parties. Although every founding party seems to have its own individual goal, three distinct groups of founders each having similar types of goals can be distinguished: (1) government agencies (local, regional and central), (2) research institutes, and (3) private companies.

Government agencies are involved in the vast majority of science parks, be it as founder, financier or otherwise. Their interest in science park development can be seen as a 'confluence' of structural changes in the world economy and of changes in regional policies. Government agencies mention various motives for their interest in science park development, such as job creation, economic growth, the restructuring of a region's economy, technology transfer, the creation or support of new technology based firms, the enhancement of research opportunities for universities, etc., but in the end these motives are derived from the wish to (1) stimulate technological development, or (2) to stimulate regional development.

Universities (or in several, public research institutes) have been the very first organizations to create a science park. First generation parks, such as Stanford Research Park, Cambridge Science Park and the Research Park Triangle have all been initiated by universities, partly to use idle land or to invest capital. In other instances, universities or other higher educational institutions have not taken the initiative, but have been approached by government agencies or private companies to perform the research function of the park. The reasons for their involvement are many.

The private sector has so far played a modest, though increasingly important, role in science park development. In general, it has followed a wait-and-see policy. The private firms which have already been involved in the establishment of a science park can be subdivided into three groups: (1) real estate developers operating purely for profit; (2) venture capitalists and high-technology firms aiming to have a 'window on technology' (this group appears to be small, probably because it is more efficient for them to invest in one of the companies located on the park than in the park itself); (3) large local firms investing in science parks for reasons of public relations and social responsibility (job creation, regional technological development). Table 2 lists the founders and their objectives.

All parties involved share also a responsibility in terms of the science park product and the market by selecting the proper candidates. The large variety of related names (e.g., incubation centre, innovation centre, technology park, business park, brain park or research park) indicates that the actual practice shows a wide diversity of policy orientations of science parks.

Table 2. Goals and founders of science parks

FOUNDER	GOALS
Government agencies	Regional development Technological development
Universities	Regional development Technological development Financial returns Expand employment opportunities Enhance prestige Use idle land Invest capital
Private firms	Regional development Technological development Financial returns Window on technology Public relations

It turns out that during the strategic planning stage the most important critical success factors from a managerial viewpoint are:

- harmonious working relationships among parties
- flexible and creative planning practices
- early establishment of formal links with a high quality research institute.

4.2 Organization

Science parks - once established - appear to exhibit a great variety of organizational configurations and cooperative modes. Table 3 gives a systematic typology of modes of cooperation by looking into both control and funding.

This table gives in a pairwise way the most common and feasible modes of partnership among the main parties involved in the development of a science park.

The extent to which a science park is a planned or is the result of a spontaneous development is of decisive importance for strategic planning, which in turn influences the organizational structure. The differences in strategic planning between European parks - where governments have a clear role in science park

Table 3. Partnerships of science park founders

Control → Funding ↓	Government	Research institute	Private firm	Property developer
Government	control by government but universities have often creative leadership (formal co-operation)	joint-venture; often a loose co-operation: more or less spontaneous development	public private partnership; government funding lowers the risks	public private partnership: government lowers risk and provides appropriate conditions
Research Institute	--	entirely owned & privately financed venture; spontaneous developed	--	--
Firms	--	firms doing part of the property development	--	private firms provide a part of the property
Property developer	--	joint-venture on a formal base; both involved in decision making	not present: science park too risky to be financed by private sector firms only	not present: science park too risky to be financed by one private firm

establishment - and the United States - where governments have only marginally been involved in science park development - are usually reflected in the legal structure of the park. For example, in the United States approximately 25 per cent is owned by for-profit corporations (see Luger and Goldstein 1991). In Europe, on the other hand, more than 60 percent of the science parks is under governmental control, while the remainder is mainly controlled by universities. In Europe, public financing and other government assistance have played a more pronounced role in science park development.

The various founding parties are able to create different types of partnerships. Since hardly any initiator, be it a research institute, government agency or private firm, has all managerial, technical and financial resources to develop a science park, it follows that critical success factors for the organization are:

- parties with complementary resources must cooperate;
- the organization structure must be chosen in accordance with the strategy of the founders.

4.3 Financing

Science parks are primarily financed by public authorities and by universities. The private sector considers them as financially unattractive. From a societal point of view, science parks can nevertheless be very attractive. We will see that this inconsistency often justifies government interference.

A science park can be seen as an investment decision with the following characteristics:

Long gestation period: it typically takes 10 to 25 years before a science park breaks even or becomes profitable. This requires sufficient patience of all parties involved; it also requires financial instruments tuned to the expected cash flow pattern of the park and the ability of the investors to provide funds in subsequent stages of development.

High capital investment amounts: especially in the first stage of development large amounts of money are required to finance land, site infrastructure and buildings of a fullsize science parks.

Involvement of various parties: this multi-party model makes the financing decision more complex than a common business investment decision.

Lack of liquidity: a financial participation in a park can only be sold after the science park turns out to be successful. In other words, exit options are virtually non-existent. This is of course an obstacle for private investors.

The cash outlays of a science park are relatively high, concentrated at the beginning of the project and can be estimated with reasonable accuracy. The cash revenues, however, are spread over the entire lifetime of the park and are difficult to estimate, because of the unique character of a science park (in terms of stated goals, location, and parties involved). The future cash revenues depend mainly on the number of tenants a science park is able to attract; it is difficult to assess this number. For these reasons, science parks are risky investment projects. The perception of the private sector is that the expected return of an equity participation in a science park cannot compensate for this risk.

Private firms, including banks, are neither inclined to extend loans to science park founders. A park often lacks collateral; if a park fails, there will be hardly any assets that can be sold to pay off debts. This is because buildings and site infrastructure are adapted to the specific needs of tenant firms and are therefore difficult to sell in case of failure.

The financing of science parks is therefore largely marked by the absence of private investors. In the United Kingdom, government agencies account for about 50 per cent of total financing of science parks; the figures for the United States and Japan are 50 and 94 per cent, respectively (see Masuda 1990, and Luger and Goldstein 1991). Figures about investments by research institutes are not available. Investments by the private sector are concentrated in a small number of parks which are located in areas which are already characterized by the presence of technology based firms. Both private parks in Japan and the seventeen fully privately financed parks in the US have all been set up in such areas; a similar situation exists in Europe, though in a less extreme form. In these cases the potential market for the product - space and services - is high, so that revenues can be estimated with more accuracy and the gestation period is likely to be relatively shorter. In addition, the value of land in these 'high tech' areas is relatively high and can serve as collateral.

Since few regions are endowed with a critical mass of new technology based firms, the vast majority of science parks is primarily financed with government money. Especially in the economically less developed regions science parks are heavily relying on public funding or semi-public funding (via state banks, e.g.).

Clearly, a science park passes through different stages of its life time and the type of financing is dependent on its evolution. This is briefly summarized in Table 4, where a distinction is made between internal (i.e., directly committed via the management of a park) and external (only financially interested) investors.

In retrospect, the most important critical success factors in the financing stages of a science park are:

- substantial financial support of government authorities
- long-term commitment of all financiers
- willingness by financiers to absorb significant losses in the initial stages of a park development.

Table 4. An overview of financiers in different stages of development of a science park

Financiers	Pre-construction	Land	Construction	Marketing	Operation
Internal investors					
Central governments	X	X	X	?	?
Local governments	XX	X	XX	?	?
Universities	XX	XX	XX	X	X
Private firms	O	O	X	?	?
Property developers	?	?	X	?	O
Venture capitalists	O	O	?	?	O
External investors					
Central governments	?	?	?	0	O
Local governments	XX	XX	XX	?	?
Universities	?	?	O	O	O
Private firms	O	O	O	O	O
Property developers	O	O	X	O	O
Venture capitalists	O	O	O	O	O

XX Financing important   ? Financing possible
X Financing available   O Financing not available

4.4 Design and architecture

The physical design and outer architecture of a science park is generally regarded as a major factor contributing to the image of a park. Landscaping is the process of making the site suitable for the science park to function. Many parks have formulated restrictions on land use are density.

Virtually all successful science parks have restricted on site manufacturing. Most of them do not allow manufacturing at all, while others only allow light manufacturing or prototype production. Polluting and dangerous activities are almost always restricted or prohibited. Landscaping issues that effect a park's image are listed in Table 5.

Table 5. Image related landscape issues

Land available for development
Volumetric ratio (floorspace / site area)
Ecological / environmental issues
Provision of residential areas and shopping centres
Provision of leisure facilities
Zoning restrictions

In terms of critical success factors, the following conditions can be mentioned:

- a prestigious outlook and imaginative architecturing
- flexible and low cost buildings that are appropriate for innovative activities and knowledge transfer.

4.5 Management

The management of a science park is different from that of a conventional industrial park in that it undertakes efforts to stimulate cooperation between its tenants and to help its tenants grow. To encourage the transfer of technological knowledge between the commercial and research function and assist on site organizations, the management team provides for various services.

Managing the park during the operational phase is considered to be a critical phase, as in this stage the park management has to prove that it is able to sell its product and become a profitable organization. It is hard however to demonstrate a positive impact of the supply of non-property elements on the benefits of the commercial, research and knowledge transfer functions. Some even doubt whether on-site management is required to stimulate interactions between tenants and the university and whether assisting tenants will resolve particular business problems (Luger and Goldstein 1991). There are however some studies which suggest a positive contribution of services to the success of a science park. For example, in the United Kingdom, one third of companies located on a science park mentioned on-site management as a reason to locate on the site. Luger and Goldstein (1991) found that US parks consider the provision of services as one of the three most important location factors.

Henneberry (1984) has divided the services that a management team can provide into four groups. The first group is *basic unsophisticated services*. These are the general secretarial services such as typing, reception, photocopying, telephone answering etc. Fax and electronic mail are also increasingly required by tenants and if provided centrally, they are cost-effective to tenants. Although science parks are set up to accommodate high tech firms, the tenant demand for these 'low tech' services is higher than the demand for more advanced services.

The second group is *technology and training services*. Contrary to basic services, technology support and training services are rarely provided on conventional industrial estates. For this reason, new high tech firms regard these services as an 'added value' of the science park concept. Tenants have access to university libraries and databases and are sometimes advised on patents and other forms of intellectual property; research institutes might also be able to carry out subcontracted R&D. Technology support can be offered by an on-site company or research institute or by an external organization.

In third group of services is *business services*, such as business planning, management consulting and marketing assistance. A particularly weak point of small firms is the formulation of a corporate business strategy and the implementation of this strategy. The management of a firm is often insufficiently aware of product/technology trends and the size of its target market, which can have considerable consequences for its future prospects. Marketing assistance is also important, as small firms are often unable to promote their products and to create the sales channels required to reach the national or international markets and thus fully exploit their products's profit potential.

Financial services is the last group of services. They are of utmost importance to small firms. Many small firms or persons with promising ideas lack the cash to realize them. Banks and other private investors are reluctant to finance them for various reasons.

As Table 6 shows, in most developed countries private funding and bank loans are the most important financing options for start-ups. Because of their modest financing requirements and high risk, venture capital is only available for the most promising small firms. A problem related to venture capital is the unwillingness of owners to lose control. A venture capital investment involves (quasi-) equity participation, which means that the firms are no longer fully owned by the founder(s). Furthermore, the concept of venture capital implies active involvement in the companies they finance until they are sufficiently developed for disposition. This involvement varies from the presence of a member in the board of directors to hands-on management, to cope with problems such as marketing and financial matters. One can therefore say, that the equity gap experienced in this stage of development is mainly the result of a management gap.

Government assistance (grants, loan guarantees, interest subsidies, etc.) is a small but growing source of finance for small firms. Unfortunately, small firms find it extremely difficult to obtain the support they are entitled to. The application process is sometimes so complicated and time consuming that most firms do not even apply for government grants.

The critical factors then for a successful management of science parks are:

- provision of services consistent with the science park's profile
- strict orientation of management strategies towards the park's needs
- attraction of some key firms ('anchor companies').

Table 6. Sources of finance for new SMEs (%)

	UK	Japan	US
Personal savings	55.0	60.2	66.2
Banks	17.1	22.4	25.0
Government agencies	16.9	2.3	3.5
Manufacturing companies	2.5	NA	NA

Sources: Monck (1988)

4.6 External environment

Given the diversity and types of science parks, various important external factors can be distinguished that enhance the viability of a science park. They are summarized in Table 7.

Table 7. External success factors of science parks

Economic factors	**Social factors**	**Environmental factors**
Risk capital Skilled labour force Related industries Infrastructure	Local support groups Entrepreneurial spirit	Desirable living environment

Most founders and managers of science parks are aware of the impact of these factors on the success of their park. If the region in which the park is located is not endowed with (all) external success factors, they sometimes attempt to 'internalize' these factors. Some parks, for instance, have created a venture capital fund to be invested in their own tenants, others organize courses in entrepreneurial management, or provide high quality telecommunication facilities.

The assumption that the availability of external success factors is positively correlated with per capita regional income is supported by Henneberry (1984) and Masuda (1990). They have shown that science parks (and especially the total acreage of parks) in the United Kingdom and Japan respectively are highly concentrated in regions with a per capita income above average. This is also confirmed by data from the US and the EC (see Table 8).

Table 8. Science parks in regions with a per capita income above national average

	Number of parks (%)	Total acreage of parks (%)
Japan	66,0	86,7
United States	65,4	81,5
European Community	49,7	68,4
United Kingdom	55,8	76,2

Source: Henneberry (1984); Masuda (1990)

Thus in conclusion economic, social and environmental factors may be seen as critical external success factors for science parks.

4.7 Concluding remarks

The above mentioned critical success factor have been identified from a broad survey among various science parks in various parts of the world. After this exploratory stage these results have been further investigated by in depth analysis of five specific science parks: Sophia Antipolis (France), the Stanford Research Park (USA), the Technopolis Project (Japan), the Hsinchu Science Based Industrial Park (Taiwan), and the Research Triangle Park (USA). The experiences from these cases supported the above exploratory notions.

Science parks appear to differ enormously with respect to their strategic goals, their formulated strategy in terms of products and markets, and in the implementation of their strategies. At first sight, it seems impossible to formulate a list of critical success factors with general validity. But in practice, most science parks do pay attention to a number of common factors which are critical for their successful development.

General speaking, science parks may act as the incubator of new technological development in a region, or they may be the result of such a development. In the first case, the region has already experienced the growth of technology based firms; then science parks, often set up by market-oriented universities or property developers, can take advantage of this situation by offering them space and services. Thus these parks have spontaneously developed. But the vast majority of science parks is set up in a region without the presence of a critical mass of technology based firms. Primarily because of the difficulty to demonstrate a market need for science parks in regions without a 'high tech' industrial base, the private sector has been reluctant to invest in such developments.

Thus, as a stand-alone project, a science park is usually not viable from a purely financial point of view: the expected return is not commensurate with the perceived risk. But the benefits of these 'forerunners of high-tech growth' must be seen in a broader context. From a long term perspective, science parks can contribute to the technological development of a region's or nation's economy. But since private investors do usually not obtain most of these benefits, many governments agencies and universities have financed the development of science parks, notably in Japan and Europe. Without this assistance it is unlikely that science park development would have existed at its current level.

There are several factors which depend on the availability of financing: a prestigious outlook, the provision of services, and the provision of basic infrastructure. Science parks can create an attractive, prestigious image to attract large knowledge-intensive companies. Such companies are often able to generate a considerable and relatively riskless stream of income. A prestigious outlook can also be created to attract skilled labour force (e.g., the Hsinchu Science Based Industrial Park, Sophia Antipolis and various Japanese technopoles). This is important, because large firms are not willing to locate in an area with a shortage of skilled manpower. It must be noted however, that a prestigious outlook is expensive; if prices rise above a certain threshold, small technology based firms will no longer be able to pay the rent. In other words, a strong emphasis on the prestige and overall image of the park may become at odds with its technology transfer function.

The physical characteristics of a science park should of course meet evident conditions to attract tenant organizations, such as the presence of a good road infrastructure.

To encourage the formation and growth of small high tech firms, science parks should also provide more advanced services. We stress the importance of basic services (such as shared fax or a centralized switchboard), technical and training services, business services and financial services. Financial assistance is especially important, since the problems of starting firms are primarily financial in nature.

Contrary to most other organizations, science parks are usually set up by different institutions with different backgrounds and different strategic goals. The reason is that hardly any organization has all managerial, technical and financial resources at its disposal to develop a park.

The goals of the different founders may conflict with one another. These conflicts must be resolved, before the science park can function as a coordinated entity. Since an organization cannot exist without agreement among the founders about its desired state, it is of utmost importance to build consensus in the strategic planning process. Needless to say that short-sighted, fragmented policy making among the government, business and university components of a science park will do harm to the achievements of a park. If research institutes and companies are to benefit from each other's strengths, a real 'think collaboration culture' has to be developed.

The importance of harmonious working relationships is reinforced by the fact that founders have to cooperate for a long period of time. The typical gestation period for a park to become profitable or to break even is between 10 to 25 years and exit options hardly exist. Especially the commitment of financiers in science park development is critical for its success. They must be able to absorb substantial losses during the gestation period. Financiers do not only need to finance the construction of the park, but also the park's management team. We have seen that government agencies are regularly involved in the financing of a park.

The goals of an organization are best realized if strategy formulation and strategy implementation are congruent with these goals ('consistent fit'). The identification of product and target market, the organizational structure, the financing mechanisms, the physical characteristics of the park, as well as the services offered, are all to be determined by the goals set by the founders. Strategic planning practices must however, be flexible enough to respond easily to economic and technological changes.

What, as a summary question, appear to be the critical success factors of a science parks? After a careful analysis of the theory and practice of science parks, they can all be traced back to:

- The availability of government financing (in particular, for science parks in regions without a critical mass of high-tech firms).
- A consistent strategy, which leaves room for flexibility and creative management.
- Harmonious, long term working relations, which are safeguarded by a nucleus of dedicated people.

In conclusion, science parks can be seen as potentially powerful policy tools for regional development, but the road towards successful engineering creativity is paved with many stumbling blocks. Overcoming such bottlenecks in each development stage of the life cycle of a science park is a sine qua non.

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